MEMORANDUM
RM-[illegible]-PR
SEPTEMBER 1969

PRAM: A PRELIMINARY REPAIR LEVEL ANALYSIS MODEL

Richard J. Kaplan, John Y. Lu and Robert M. Paulson

PREPARED FOR:
UNITED STATES AIR FORCE PROJECT RAND

The RAND Corporation
SANTA MONICA • CALIFORNIA

97

AD 676271

MEMORANDUM
RM-5752-PR
SEPTEMBER 1968

PRAM: A PRELIMINARY REPAIR LEVEL ANALYSIS MODEL

Richard J. Kaplan, John Y. Lu and Robert M. Paulson

This research is supported by the United States Air Force under Project RAND—Contract No. F44620-67-C-0045—monitored by the Directorate of Operational Requirements and Development Plans, Deputy Chief of Staff, Research and Development, Hq USAF. Views or conclusions contained in this study should not be interpreted as representing the official opinion or policy of the United States Air Force.

The RAND Corporation
1700 MAIN ST. • SANTA MONICA • CALIFORNIA • 90406

This Rand study is presented as a competent treatment of the subject, worthy of publication. The Rand Corporation vouches for the quality of the research, without necessarily endorsing the opinions and conclusions of the authors.

Published by The RAND Corporation

PREFACE

This Memorandum describes a model developed to analyze the Repair Level Decision (RLD) process. It was developed to satisfy a requirement of the joint AFLC-TAC project PACER TACK. This project is being conducted to examine methods and costs associated with improving the mobility of the recently reorganized Tactical Fighter Wings.

The Preliminary RLD Analysis Model (PRAM) is designed to examine the cost trade-offs that can be made in doing parts repair in the field or at a centralized location. The current model is an extension of the analysis suggested in H. S. Campbell, Initial Support Planning: Problems and Methods, The RAND Corporation, RM-3845-PR, September 1963. The model is currently programmed for the JOSS time-sharing system but can be easily translated to other computer operations.

The model has been made available to the PACER TACK project at Ogden Air Materiel Area and has been briefed to AF personnel from Hq OOAMA, Hq AFLC and Hq TAC. Comments and suggestions received from these sources have been incorporated in the final version of PRAM included as an Appendix to this Memorandum

SUMMARY

The Preliminary Repair Level Decision Analysis Model (PRAM) described in this Memorandum was developed to examine some of the cost trade-offs that exist between Aerospace Ground Equipment (AGE) and recoverable end items. Recoverable spare parts can be repaired in the field at base level or at a centralized (depot) location. This model provides a straightforward method of organizing the relevant cost and item data into sets of cost aggregates and item levels for convenient comparison and analysis.

The model is intended for use when trade-off sensitivity testing is indicated. Its use is not appropriate for evaluating AGE that is required to support flight operations. In aggregating the costs used in the comparison, two cases of repairability are considered. Both involve the relative costs of support with and without the AGE at base level. In the case without AGE, the model aggregates the cost of spares stock levels, the cost of shipment to and from the depot and the cost of depot repair. These costs can be compared with the costs incurred in a support system with base AGE, which includes the cost of AGE itself, a smaller stock level of end items, the costs of shipment to and from a depot at a smaller rate, the cost of repair at both depot and base in the proper proportion, and all other costs associated with repair in the field. The results are presented in two modes, one mode employs an optimal inventory leveling technique to develop the alternative stock levels. This method enables the user to make a direct comparison of costs since the performance of the two alternatives has been equalized through a uniform backorder policy criterion.

The other mode portrays the comparison when current Air Force stock leveling policies are employed to develop the alternative stock levels. In this mode, no attempt is made to equate system performance. As a consequence, it may be difficult to interpret cost differences.

Using the model as an evaluation device, the Memorandum includes a brief parametric analysis. The examples include an examination of

the sensitivity of cost to demand rate and NRTS (Not Reparable This Station) rates as well as the interaction between demand rate and the end-item/AGE cost ratios.

In the final portion of the Memorandum, some of the problems of cost allocations are discussed as well as strategies for employing the model. The concept of aggregating AGE units into shop sets is recommended whenever joint use problems are encountered. In this case, where one piece of AGE services multiple end items, the analysis can be made by apportioning the AGE cost over the end items according to the demand that each places on the AGE and summing the results of the individual calculations. Appendix A contains a JOSS program for the model; Appendix B contains an example of the JOSS product; and Appendix C contains a series of products illustrating a cost allocation method.

ACKNOWLEDGMENTS

The authors wish to thank the members of the PACER TACK organization, in particular Lt Col H. A. W. Tibbs, and the members of the RAND group working with them for stimulating the effort that resulted in this study. We are grateful also to Jay Williams of Hq AFLC and James Stucker of RAND for volunteering many useful comments that have measurably improved the final product. The inadequacies that may remain are the responsibility of the authors.

CONTENTS

I. INTRODUCTION

This Memorandum deals with some specific aspects of the Air Force's Repair Level Decision (RLD) management system. It describes a model that was developed to systematically organize and evaluate some of the cost, repair, AGE (Aerospace Ground Equipment), and item data that provide the basis for evaluating a range of rational RLD policies.

BACKGROUND

Other RAND Memoranda and Air Force test programs have provided much background and information on the same subject matter. The decision process itself is fundamental to the logistics posture of each new system introduced into the weapons inventory and to the long-range requirement for support resources of all types--personnel, facilities, equipment, and spare parts. Each part of a new weapon must be evaluated during the design and testing processes to determine first, whether it should be repaired or not, and then where the repair should be done--in the field or at some central location. Most decisions affect more than one part and more than one set of resources. In some instances, the end system is designed to a set of concepts that preset the direction of the repair decisions. Certain systems or systems of the weapon must achieve specific operational objectives (e.g., minimum turnaround times, self-test features, etc.), and thus the logistics environment is defined, and as a consequence, these requirements tend to dominate other cost-benefit considerations. In other systems, trade-offs can be evaluated which highlight the accommodations that can be worked out between operational and cost-effective support postures. It is with this latter set of conditions that the model presented herein is concerned.

The basic decision process was discussed by H. S. Campbell in Initial Support Planning: Problems and Methods, The RAND Corporation, RM-3845-PR, September 1963. The method of evaluation suggested in this Memorandum provides the point of departure for the development of a host of methods for making the RLD evaluation.

In 1966-1967, the AFLC and PACAF jointly conducted Project PACER (LOGGY) SORT, a special overseas repair test. One of the objectives of this test was to obtain data on which to evaluate some of the consequences of the RLD in the context of AFR 66-27, Base Self-Sufficiency Program. This regulation, which reads in part, "The USAF maintenance objective is to achieve maximum maintenance at the organizational and field level," had provided the background for most of the maintenance concepts developed up to the time of the test. The test objectives of the reevaluation of this concept and the development of "optimal" field maintenance concepts as an alternative, led to the present evaluation of the RLD being conducted as a part of Project PACER TACK. The overall objective of this project is an evaluation of a reorganized, highly mobile, tactical fighter wing. It is obvious that the RLD, defining as it does the place where repair will take place, can have a large impact on the mobility of any tactical unit. The RLD must therefore include a specific consideration of the consequences of mobility requirements in the development of decision alternatives.

OPERATIONAL REQUIREMENTS, RESOURCES, AND COSTS

Decisions on the addition or placement of AGE with an operating unit must be primarily influenced by the necessity to meet its flying and fighting mission. Thus, the equipment to preflight, fuel, arm, recover, and postflight aircraft must always be made available. To the extent that some of these requirements have colateral capability and availability to accomplish field maintenance and parts repair is a bonus value. In considering a unit of AGE or a shop set of AGE then, the requirement for its role in meeting the flying requirement must transcend any cost-effectiveness value that could be developed for it. In other words, a cost analysis of the type performed by the PRAM model is meaningful only when applied to situations in which the option of accomplishing repair function either in the field or at depot is available.

A second consideration is whether the AGE can be used in isolation or must be part of an integrated shop facility. In the RM-3845 analysis, it was found to be practical to aggregate AGE units to a repair facility or shop level and make an effectiveness evaluation on the basis of the shop. When mobility is explicitly considered in the evaluation, this concept may become less practical and a piece-by-piece evaluation may be appropriate. Hence, PRAM is applied with the assumption that an AGE item can be useful by itself. If the joint-use characteristics of AGE items are pronounced, then the aggregate approach of RM-3845 or some modified application of PRAM as discussed on p. 25 should be considered.

MOBILITY CONSIDERATIONS

A separate issue can also be evaluated--the decision with respect to the movement of a particular AGE or repair capability on a specific deployment. This issue is distinct from the decision of whether or not to provide the equipment to do field level repair at all. One could state that the RLD decision itself must consider the number of deployments that could be expected over the life of the weapon, and hence, consider as a cost either the number of times the weight represented by the AGE and its support equipment or, alternatively, the number of times the spares in the WRSK must be moved. Since this cannot be specifically forecast, however, and since the spares-AGE weight trade-off is not critical unless the number of deployments becomes large, this subject is not central to the primary RLD process.

The RLD model presented here can be used to assess a single unit's deployment strategies with respect to the movement of a given repair capability. This deployment decision can be evaluated for a given squadron or wing--once the AGE has been made available after an RLD decision process. The deployed-units demand rate for an end item can be evaluated in the item stockage-AGE trade-off mode. From the product, a decision about whether to deploy with or without the AGE can be made. In this type of evaluation, the cost of the AGE can be set to zero, since the AGE is already available, and the only repair capability costs that are germane are those concerned with transportation (weight and rate) and AGE operations (power, shelter, spares, etc.).

ELEMENTS IN THE EVALUATION

AGE provides test and repair capability. If we want to determine the marginal value of this capability, we must place a value on the output the capability produces and make some estimate of the costs of putting the capability into operation. If the operational value exceeds or nearly equals the cost in a given scenario, then we must make a repair level decision in favor of adding the capability.

The problem of determining the elements of value and cost is, at the outset, no easy task. Many items that should be considered cannot be quantified, and even those that can may take on values highly dependent on the time horizon that is being used to make the evaluation. High initial costs can be washed out if a sufficiently long evaluation period is used. Many day to day operations have not been subjected to detailed cost studies, and therefore cannot be explicitly considered. Many that have, are in reality joint cost operations, and hence, any allocation scheme that may apportion costs on an item basis must be arbitrary, and is subject to conflicting interpretations.

Despite these problems, it is possible to list the elements that may have a bearing on the RLD process, and it is possible to build a logical grouping of costs and benefits (a model) to make a meaningful evaluation. Below, we list some of the elements that must be evaluated as a cost or gain from the addition of an AGE unit of capability to any operating environment.

THE BENEFITS

1. Added Flexibility. This element is difficult to quantify; however, additional capability always provides the materiel manager with an increase in the range of options available in any maintenance situation. With the added capability, he not only has the option to send materiel off-base for repair and to get off-base support, but he can do the job locally and, in a sense, control his own response possibilities.

2. Greater Responsiveness. The value of response can be quantified in the case of end item stock level reductions. Techniques have been developed to estimate the value of a day of stock throughout a network of bases and the support

system.* If the base is more responsive in producing serviceable parts because of base repair capability, this is a meaningful gain. In addition, a local repair capability may provide support when external sources are cut off or restricted because of tactical conditions. The base materiel manager with a repair capability can control the response of his system by expediting or deferring to meet the operational requirements of any situation.

3. Reduced Recoverable Item Inventories. Techniques are now available to compute the stock savings possible from an enhanced base repair capability. Reduced inventories are particularly important when dealing with high-cost, high-demand items. Whenever inventories can be reduced, savings occur in transportation and holding costs. Initial investment cost savings are one-time savings, but transportation and holding cost elements (including obsolescence and storage costs) are recurring for the life of the system.

4. Other Savings. By doing work in the field, work may be avoided or eliminated completely at depot level. When this happens, the costs of packing, crating, handling and loss in shipment are reduced. The need for the continued employment of a scarce airlift capability for resupply purposes may be minimized. Airlift will be required for the deployment operation only and, to a large extent, the repair capability develops true base self-sufficiency.

In summary, the dollar savings attributed to the capability AGE provides are primarily in the investment and transportation areas. If these are not dominant in any analysis, the balancing factor may always be the increased flexibility and more controllable response that the AGE provides the deployed unit.

THE COSTS

There are a wide range of elements that can be quantified on the cost side of the coin. Some are important in all situations and some only when deployments to bare bases are considered. Many involve joint cost allocation decisions and are not clear cut with respect to any one unit of AGE. In this area, it probably would be practical to consider AGE and end items by shop set, and thus avoid many

---

*R. M. Paulson, H. S. Campbell, and D. M. Landi, An Analysis of Peacetime Resupply Response Requirements in the European Theater (1966), The RAND Corporation, RM-5681-PR, July 1968.

allocation questions. The more important cost elements include the following:

1. <u>AGE Costs</u>. These charges are specific to any evaluation. The method of application may be tempered by joint cost-allocations procedures and amortization schedules--both of which are arbitrary. However, there is a real one-time system expenditure for the AGE that must be absorbed in the cost model. In some instances, the AGE also requires support and calibration equipment for useful service. The cost of these supporting resources must be allocated to the end-item of AGE when making the evaluation.

2. <u>Personnel Costs</u>. This cost is difficult to quantify. If more than just a remove-and-replace maintenance policy is implied by the utilization of a repair capability supplied by the AGE, there may be additional personnel costs. Generally speaking, higher skill levels are required to do a repair job, and as a consequence, both more personnel and higher ratings are required. In addition, there is the cost of the additional personnel overhead required to support the increments of personnel added. This overhead includes messing, medical, recreation, welfare, and security services. The costing of these incremental personnel is further complicated because skilled personnel can be used in a wide variety of jobs and joint cost allocations must be made. The net of all these cost considerations must be utilized in making the cost-benefits analysis.

3. <u>Facilities Costs</u>. The cost of the facilities needed to support the AGE evaluation may be another joint costing problem. Facilities include requirements for shelter, power, and environmental control. Most AGE for parts repair require some or all of these facilities, and it is probably most convenient to deal with these item costs in shop sets. In many instances, it is possible that the cost of support facilities will dominate the AGE costs. Amortization schedules can have an effect on the application of these costs to the AGE evaluation.

4. <u>Spares Support</u>. With the addition of a repair capability, it becomes necessary to stock both spare parts to support the repair operation and spare parts to support the AGE and the required facilities and calibration equipment. These spares must be transported and stocked at the operating base and thus are costs that must be charged to the system evaluation. While no additional repair parts will be consumed in the item repair system, additional spares support will be needed to support the multiechelon aspects of the stock control system and to support the additional AGE and facilities deployments. These marginal costs will be difficult to determine.

5. <u>Technical Data Requirements</u>. This is probably a minor item in the cost analysis framework. For each end item and piece of AGE added to a deployed repair facility, however, there must be an accompanying increment of technical data. This data can add both costs and weight to any deployment scheme. Over a long period of time, the maintenance of the currency of the data can be a difficult administrative task.

6. <u>Transportation Costs</u>. In general, the overall transportation costs will be less for the self-sufficient system than for the centralized support system. The AGE, facilities, personnel, data, and spares support must be transported to the deployed base with the initial support increment, however, or the planned support operation may not be realized. This may strain the deployment resource application schedule even though it is a cost-effective method of operation. The system evaluator must consider these deployment problems when assessing model results.

7. <u>Other Considerations.</u> Things more difficult to quantify include such elements as POL for power supplies, security for repair operations, additional requirements for cooling water, and facilities vulnerability.

All the cost elements discussed above require some investigation by the decisionmaker to determine first, if they should be considered, and next, if they affect the evaluation process. The next section includes a proposal for an RLD evaluation model. Most of the elements discussed above are included. In addition, the model uses an optimal inventory technique to determine the effect of the repair capability on stock levels. In the final section, we will discuss some methods for applying the model to both unit and shop set evaluation decisions.

II. THE MODEL

The model developed to perform the straightforward analysis described here runs on the JOSS* system at RAND. The complete program is listed in the Appendix.

STOCKAGE COSTS UNDER ALTERNATIVE SUPPORT POSTURES

One key element in comparing the total costs of base logistics support posture with AGE and without AGE is a difference in the stockage investment of recoverable items in the two cases. This section describes a method for computing stock levels for recoverable items under the alternative assumptions regarding AGE availability.

The basic premise of the proposed method is that it is desirable for base supply to provide its maintenance customers an equal level of support whether repair can be accomplished at base or not. Since it is implicit in our analysis that base repair time is shorter than the order and shipping time from depot stock, one can expect that base supply would be able to provide service of equal quality with less stockage of spares when AGE is at base than when all repair actions have to be deferred to depot.

The expected number of units in backorder at a random point in time is used to measure the degree of support given by base supply. A statistical interpretation of this measure is as follows: Suppose one goes into base supply a number of times, and each time one counts the number of units in backorder.** The average of these counts gives a statistical estimate of the expected number of backorders. This measure has been used in other stockage studies at RAND*** and was found to be more desirable than more conventional performance measures such as fill rate. Our notion of providing the same degree of support

---

*JOSS is the trademark and service mark of The RAND Corporation for its computer programs and services using that program.

**In the Air Force supply terminology, this is the number of due-outs to maintenance.

***See C. C. Sherbrooke, METRIC: A Multiechelon Technique for Recoverable Item Control, The RAND Corporation, RM-5078-PR, November 1966.

is to equate the number of backordered units in one case to that of another. We feel that this is appropriate because an organization's (say a squadron's) flying activities, hence its demands for spare parts, will be the same whether it has AGE or not.

METHOD OF COMPUTATION

Let Case 1 and Case 2 refer to analyses with AGE and without AGE, respectively. To compute the expected number of backorders for each case, we need first to calculate their respective average resupply times, t_1 and t_2. In Case 1, a certain proportion (α) of reparables will be repaired at base with an average repair time of, say, τ, and the rest will be shipped to depot or other sources in exchange for serviceable units with an average order and shipping time of, say, T. In Case 2, since AGE is not available, no repair action takes place at base and reparables will have to be returned for serviceables from depot. We then have

$$t_1 = \alpha\tau + (1-\alpha)\, T,$$

$$t_2 = T.$$

Let $P(\cdot\,|\lambda)$ denote the probability distribution of demand with mean λ, where λ is mean demand per unit time, e.g., a daily demand rate (DDR). Let B(s) denote the expected number of backorders, which is a function of a stock level s. The expected backorder functions for Cases 1 and 2, $B_1(s_1)$ and $B_2(s_2)$, are

$$B_1(s_1) = \sum_{x > s_1} (x-s_1)\; p\,(x|\lambda t_1)$$

$$B_2(s_2) = \sum_{x > s_2} (x-s_2)\; p\,(x|\lambda t_2)\,.$$

The problem of finding those stock levels that will provide a same degree of protection to both cases can now be stated concisely as follows:

Suppose we select ϵ to be the maximum number of backorders that we will tolerate. Find the smallest integers s_1 and s_2 such that

$$B_1(s_1) \le \epsilon \quad \text{and} \quad B_2(s_2) \le \epsilon \ .$$

In other words, we look for the lowest stock levels that will satisfy the specified backorder condition.

NUMERICAL EXAMPLE

Suppose we set

$$t_1 = 6.65 \text{ days}$$

$$t_2 = 13 \text{ days}$$

$$\lambda = 0.5 \text{ units per day.}$$

If we assume that demands follow a Poisson distribution, $B_1(s_1)$ and $B_2(s_2)$ can be expressed as follows:

since $\lambda t_1 = 3.23$ and $\lambda t_2 = 6.5$,

we have $$B_1(s_1) = e^{-3.23} \sum_{x>s_1} (x-s_1) \frac{3.23^x}{x!}$$

$$B_2(s_2) = e^{-6.5} \sum_{x>s_2} (x-s_2) \frac{6.5^x}{x!} \ .$$

These two functions are tabulated in Table 1.

Table 1

BACKORDER FUNCTIONS

s	$B_1(s_1)$	$B_2(s_2)$
0	3.32813	6.50000
1	2.36399	5.50150
2	1.51919	4.51278
3	.87300	3.55582
4	.44714	2.66766
5	.20459	1.89134
6	.08405	1.26038
7	.03121	.78690
8	.01054	.45966
9	.00326	.25123
10	.00093	.12862
11	.00024	.06178
12	.00006	.02790
13	.00001	.01187
14	.00000	.00477
15	.00000	.00181

If a selected value of ϵ is 0.1, the solution is $s_1 = 6$ and $s_2 = 11$. The backorder functions and the process of finding the desired stock levels are also depicted in Fig. 1.

The computation described in this section is embedded in the JOSS program described in the remainder of this section.

INPUTS

To get a rapid appraisal of the relative merits of having the end-item repair performed at base level or at depot level, the analyst must estimate the following list of inputs:

1. Cost of repair at base in dollars per maintenance man-hour
2. Cost of depot repair in dollars per maintenance man-hour
3. Shipping costs of both AGE and end items in dollars per pound
4. Daily demand rate for the end-item
5. Order and shipping time for end-items in days
6. Maximum tolerable backorders

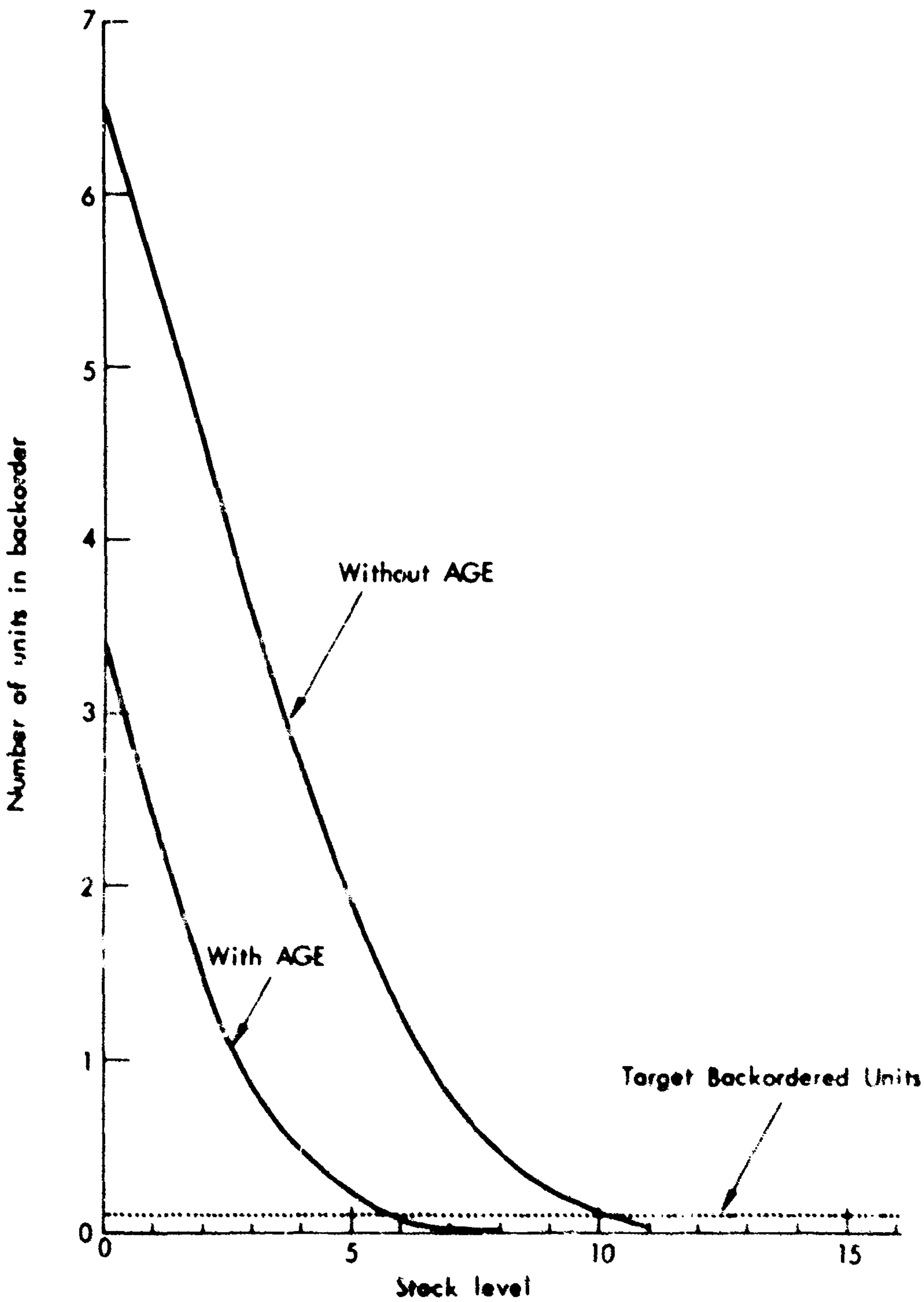

Fig. 1 -- Expected backorder functions

7. Cost of a unit end item in dollars
8. Cost of AGE in dollars
9. Expected life span of AGE in years
10. Weight of the AGE in pounds
11. Number of bench-checked-and-repaired actions
12. Number of bench-checked-and-found-serviceable actions
13. Number of NRTS actions
14. Number of condemned actions*
15. Mean elapsed time for bench-checked-and-repaired actions
16. Mean elapsed time for bench-checked-and-found-serviceable actions
17. Weight of unit end items in pounds
18. Mean repair time per job in man-hours to fix
19. Mean repair time per job in man-hours to condemn or find serviceable
20. Cost of additional technical data for base parts repair required for both AGE and end items
21. Weight of additional technical data for base parts repair required in pounds
22. Cost of additional facilities and power for both AGE and end items in dollars
23. Weight of additional facilities and power in pounds
24. Cost of additional spares for both AGE and end-items in dollars
25. Weight of additional spares in pounds
26. The discount factor

Estimates of these inputs will be gross, in many cases, since knowledge, especially with regard to items still in the design stage, will be less than perfect. Since the model runs so quickly and easily, however, testing the extreme ranges for the input parameters that have the highest uncertainty will provide information on how critical the parameter is.

---

*Note that the figures asked for in 11, 12, 13, and 14 will most likely be derived from either base maintenance data or from contractor estimates. Since these figures are used in the calculations only as ratios, they may be for any period.

The model assumes no interaction between the AGE and the multiple end items it might service. If we could estimate the number of end items on which the AGE could be used, AGE cost could be allocated to the individual end items in proportion to the demand that each end item places on the AGE, and then the costs arrived at by these sub-calculations could be combined in making the repair level decision. A numerical example of such a case is given in Sec. III.

OUTPUTS

For each of the two conditions (1) no AGE available at base level, i.e., all end-item repair is performed at the depot, and (2) AGE available at base level, the following five computations are made:

1. Optimal Stock Level. This shows the number of units of an end item that must be stocked at the base for each Repair Level Decision. In making this computation, it is assumed that a Poisson process describes the arrival rate of demands for the end item at base.
2. Total Stock Cost. The figure here represents the dollar cost of stocking the required number of units of end-item at the base under each of the two RLDs.
3. Yearly Operating Costs. The cost of operating the system under each RLD per year is shown under this heading. It do s not take into account the shipping cost for the AGE and, therefore, represents only the ongoing costs after the equipment has been positioned.
4. Five-Year Operating Cost. This figure gives the relatively long-term costs of the two RLDs expressed in terms of their present values.
5. Five-Year Total Costs. This figure adds to the five-year operating costs the stockage cost over that period.

COMPUTATION

The number of spares required is computed in the demand portion of the model as described above. The Stockage Cost displayed in the second row of the output table is calculated by multiplying the stock level by the unit cost per item. The yearly system operating costs are simple unweighted sums of the component costs for the cases of no AGE at base and AGE at base. For the no AGE instance, we add the cost of depot repair and the shipping costs and multiply this by the yearly

demand rate for the item. When AGE is available at base level, we calculate the depot repair costs in the same manner as with no AGE, but only for the NRTS portion of the demands. We then add to that cost the base repair costs and the yearly amortization charges for the AGE involved based on its expected life span. Estimates for the additional base costs for spares, facilities, and technical data are also included in this figure. The five-year system costs displayed in the last line of the output table add five times the yearly operating costs to the cost of shipping the required end items and, in the case of base level repair, the cost of shipping the AGE.

The foregoing text is condensed into the following word equations that describe the calculations performed in the model.

1. Stock Cost = (Stock Level) x (Unit Item Cost).
2. With No AGE: Yearly Operating Cost = (Cost of Depot Repair per Item + Shipping Costs per Item) x (Yearly Demand Rate).
3. With AGE Available: Yearly Operating Cost = (Proportion of non-NRTS Item) x (Cost of Base Repair per Item) x (Yearly Demand Rate) + (Proportion of NRTS Items) x (Cost of Depot Repair per Item + Shipping Cost per Item) x (Yearly Demand Rate) + (Yearly AGE Amortization Cost) + (Additional Yearly Cost for Spares, Technical Data and Facilities).
4. With No AGE: 5-Year Operating Cost = (Discount Factor* x Yearly Operating Cost with No AGE) + (Stock Level x Shipping Cost per Item).
5. With AGE Available = 5-year Operating Cost = (Discount Factor* x Yearly Operating Cost with AGE Available) + (Stock Level x Shipping Cost per Item) + (Shipping Cost for AGE).
6. Total 5-Year Cost = (5-Year Operating Cost) + (Stockage Cost).

---

*For this computation, the discount factor applied is $[1-r^5]/[1-r]$, where r is 1 minus interest rate. This factor is obtained as follows:

Let C be yearly operating cost. The present value of the 5-year operating cost is

$$C + rC + r^2C + r^3C + r^4C = C\,\frac{1-r^5}{1-r} \quad .$$

Part 3 of the JOSS program contains the major elements of the computation and is largely self-explanatory. A few things, however, should be pointed out for clarification. The term n(3)/N appears in b(2) and b(3) because the NRTS portion of the end items must be sent to repair even with AGE available at the base. The term L x 360, where it appears, adjusts the computations to supply the yearly figures, and the term P/y in step 3.22 adds the per-year cost of the AGE based on the expected life span of the equipment.

All the input data must be inserted at the beginning of a problem. Thereafter, a single entry may be charged and the computations redone with the instruction "Do Part 7." Recomputation and output requires less than one minute, making extensive sensitivity testing a relatively simple matter.

To facilitate sensitivity testing where a number of parameters may be changed in the course of a run without having to make inputs after each output, the following JOSS instructions are indicative of a method that might be employed:

```
40.1  Do part 41 for L = .05 (.10).35.
41.1  Do part 42 for P = 20,000, 50,000, 125,000.
42.1  Do part 7  for p = 2500(2500)7500.
      Do part 40.
```

The PRAM calculation of the stock level is referred to as "optimal" in the output format since that is the level required to provide equal protection under both of the conditions being observed. Equal protection means that whether the repair is done at base or at depot, base supply provides the same level of support effectiveness to the operating squadron. The effectiveness here is measured by the number of units in back-order at a random point in time. So that a comparison can be made between the two conditions considered here, we feel that it is essential to maintain the equal protection concept when the costs are computed.

The Air Force, however, does not use the method of computing stock levels we have specified, but rather applies the rules set down in Chapter 11, Vol. II, Part 2 of AFM 67-1. Part 8 of the JOSS program calculates stock levels according to the Chapter 11 formulations to allow a comparison between the two methods if desired. In this case the output table has an added line giving the figure for the number of units in back order in each case, so that the user can also consider the level of protection being given in making the repair level decision. The parameter "B" (maximum tolerable number of units in back order) in the PRAM calculations does not apply in this instance.

Appendix B is an example of the product the model produces on JOSS.* While the item parameters used in producing this analysis have no relevance to any particular item, the example does highlight the kind of decision dilemma that use of the AFM 67-1 leveling policies can produce. With the optimal stock level analysis, the case to provide the AGE is rather clear cut. It is not clear cut with respect to the Chapter 11 procedures. Here while the costs are lower, the probability of a unit being back-ordered is more than twice as high in the AGE available case. It is obvious that there is no simple relationship between cost and back-order rate, and the utility of this portion of the model product is marginal.

PARAMETRIC ANALYSIS

The following hypothetical examples are given to show how the model can be used. We fixed many of the environment parameters to conform to what we thought was typical of the Air Force operating environment as follows: The costs of base and depot level repair (d(1) and d(2)), were set at \$10 and \$17, respectively, and the cost of shipping (d(3)) was set at 10¢ per pound. Order and shipping time (T) was set at 14 days, to conform to the overseas operating situation, and .01 was used as the maximum number oi . back-order condition (B).

---

*The model has been programmed for RUSH system users by PACER TACK personnel at Hq Ogden Air Materiel Area (OOAMA).

Eight years was taken as the expected AGE life span (y). The number of actions for checked-and-repaired, checked-and-found serviceable, and NRTS (n(1), n(2), and n(3)), were assumed to be 80, 20, and 30.

The mean times for bench-check-and-repair and bench-checked-and-found-serviceable (a(1) and a(2)) were fixed at 120 and 24 hours, respectively, and the repair man-hours per job (r) was set at 5 for both depot and base repair. The weights of the end item and of the AGE are taken to be 25 and 500 pounds, respectively. In the first example, the variables whose ranges of sensitivity we are testing are the Daily Demand Rate (L) and the costs of both the unit and item and the AGE (p and P). Items 18-23 on the input list above were not considered and were therefore set to zero.

Figure 2 is a plot of the five-year total cost on the vertical axis against the Daily Demand Rate and, as might be expected, the cost increases as the demand goes up. The dotted line is the plot for all repairs done at the depot, and the four solid lines are plots that differ according to the cost of the AGE ranging from $25,000 to $200,000. The end-item cost in all the conditions was $10,000. The point at which the solid lines cross the dotted line indicates the demand level that must be anticipated in order for AGE to be economical at the amount represented by that line. If, for example, the cost of the AGE were $50,000, a demand rate of .12 or about 3-1/2 per month would be necessary to make it worthwhile to have the AGE. If the demand were lower than this figure, it would be more economical to perform all repair at the depot. Note that within the range of the parameters we are considering, nowhere would it be worthwhile to pay as much as $200,000 for the AGE.*

Our second example is directed toward the consideration that while the presence of AGE allows base level repair of the end item, a certain portion of these end items will still have to be NRTSed or

*One interesting hypothesis that could be made from an analysis of this type is in connection with the procurement of new AGE. Justification for the purchase of high-priced AGE requires that the AGE utilization be high; this might imply that end item reliability is low. This hypothesis may be evaluated by Air Force provisioning teams during the initial provisioning process.

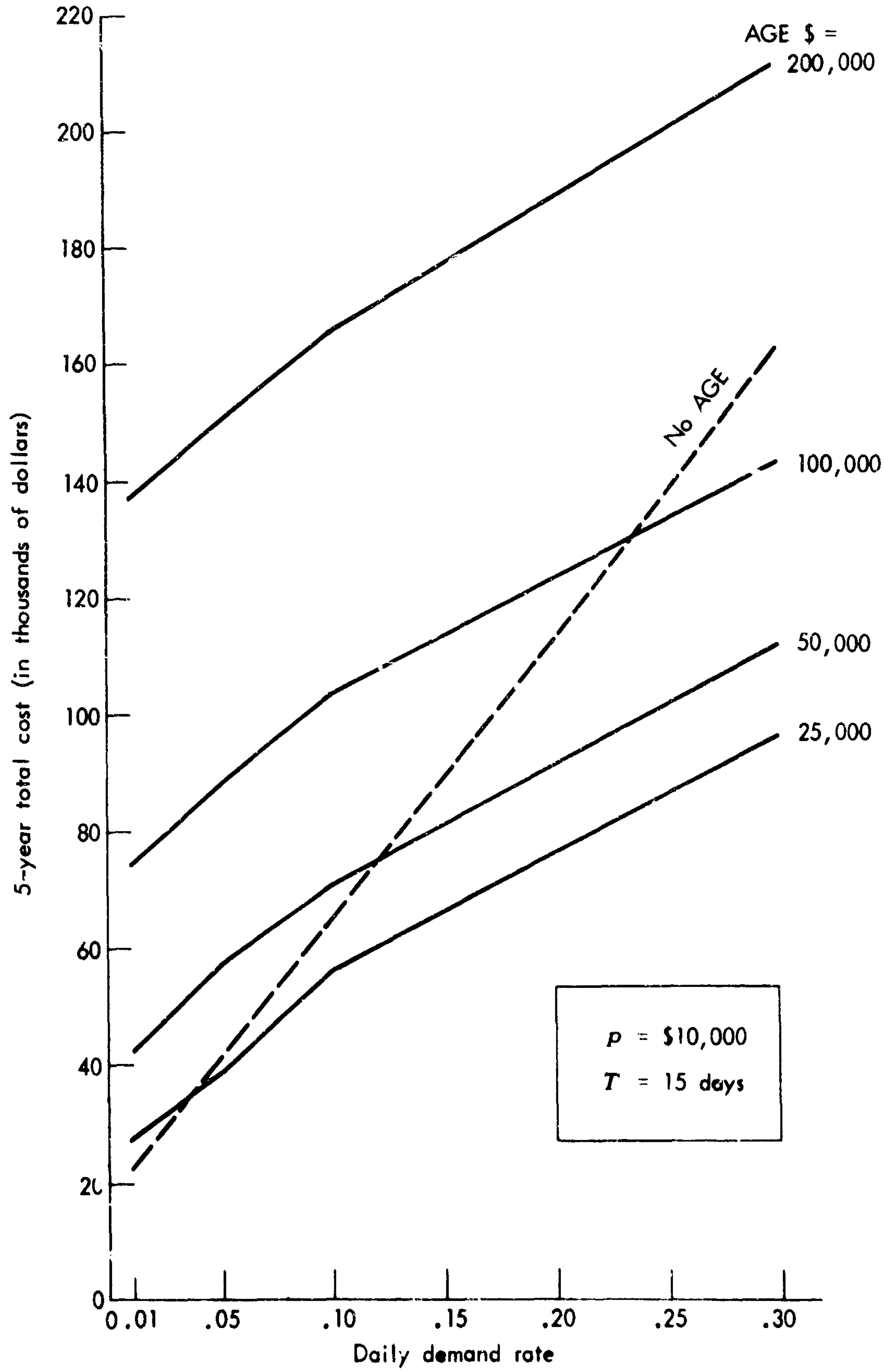

Fig. 2 -- Effect of daily demand rate and AGE cost

sent back to the depot for repair. The five-year total cost in Fig. 3 is plotted against the NRTS rate, with the costs of the end item and the AGE set arbitrarily at $10,000 and $100,000. The demand rate was taken at .30 and the order and shipping time at 14 days. The cost for not having AGE available, of course, does not change because there is a 100-percent NRTS rate, represented by the horizontal line at $150,000. For the AGE case, however, as the NRTS rate increases, the cost also increases with a crossover point with the No AGE case at about 19 percent. From looking at this chart it is obvious that the NRTS rate must be kept below 19 percent in order for AGE at base level to be economically justifiable.

Another test was run to determine whether the cost of AGE is sensitive to the value of the end item being repaired. The results of this analysis are described by Fig. 4. The model was run for the three different end item values shown and for the three demand rates of .05, .15, and .25 items per day; for each of these nine conditions, a range of AGE costs was used. The standard costs from AFLCM 375-1 were used in this test. From the output of the model, we calculated the cost at which it became more economical to repair at base rather than at depot. These crossover costs were then transformed into ratios to display in Fig. 4. As might have been inferred intuitively, as the demand rate rises, there is a willingness to pay more for the AGE in each individual case. What is surprising is the striking differences in how much of an increase can be tolerated as the cost of the end item gets large. For the $10,000 item and a demand rate of one item every four days, AGE has to cost almost $750,000 before it becomes uneconomical to make the repairs at base. This means that if only economic considerations were taken into account, it would be wrong to have a general rule of thumb to the effect that cheap items should be repaired at base and expensive items sent back to the depot. With rising daily demands for a reparable item, it becomes more advantageous to make the repair at base, and this rule becomes stronger as the cost of the item rises.

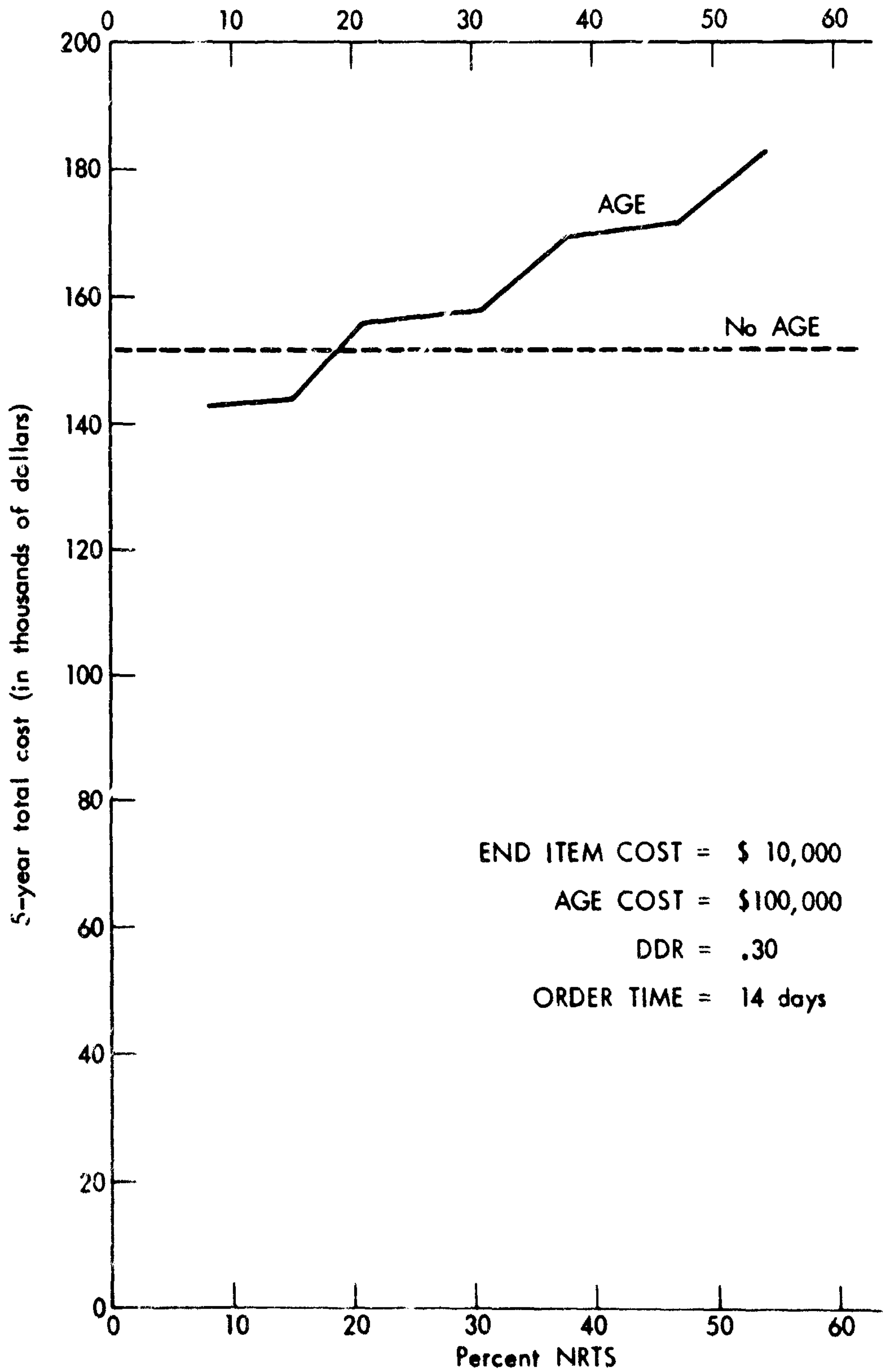

Fig. 3 -- Effect of NRTS rate

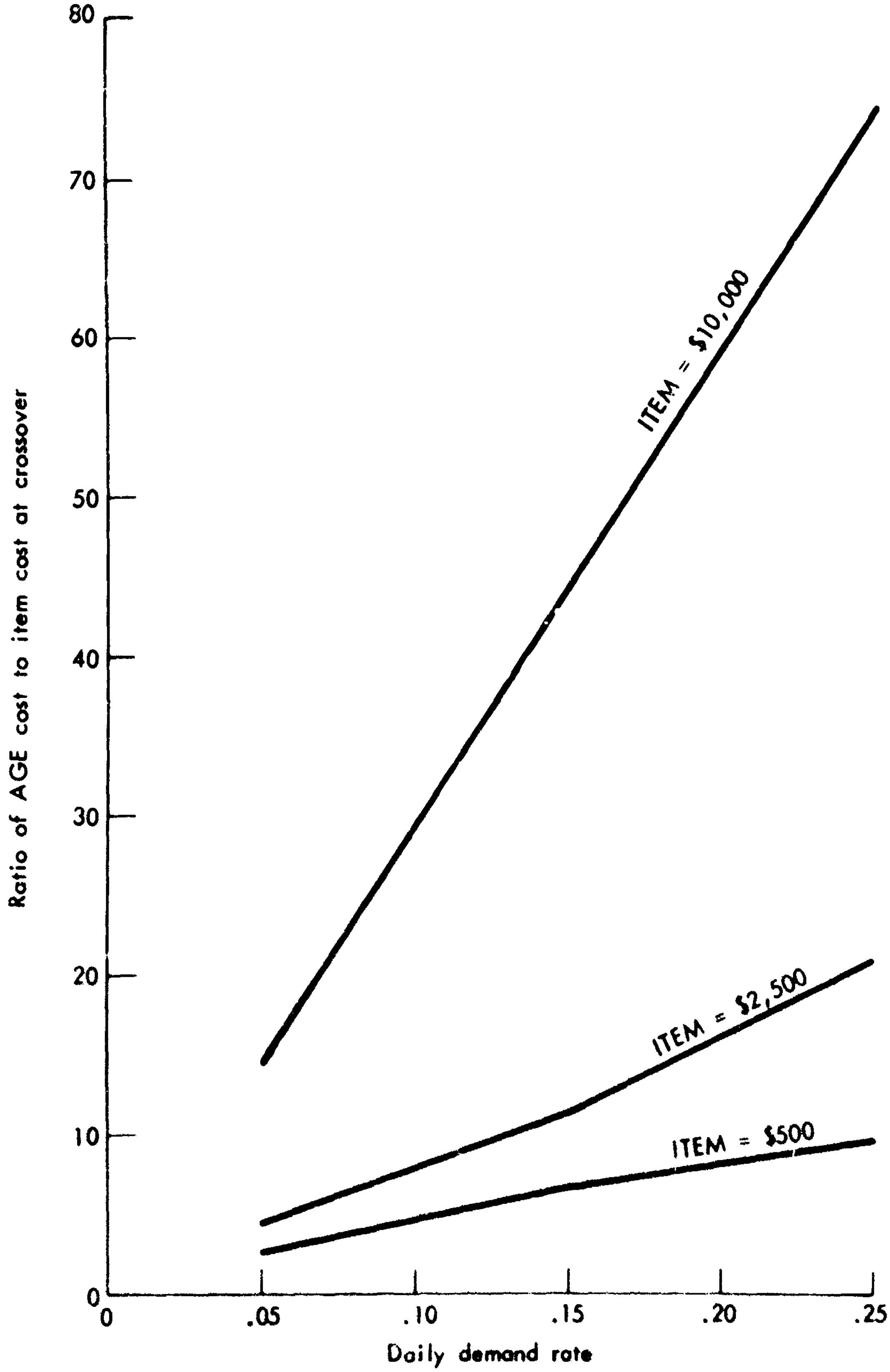

Fig. 4 -- Economic cost ratios of AGE to end item

III. EVALUATION STRATEGIES

The model, while designed to handle a single item evaluation, can be varied to satisfy a great range of AGE-item, cost-benefit problems. By combinations of items, AGE, and facilities, many questions involving joint costs can be resolved. We mentioned some of these problems in the discussion of costs included as a portion of Sec. I; here, we will make some specific points.

FACILITIES

Most cost exercises do not specifically consider facilities in the single-item decision process. This model specifically provides for these items as variables. On a fixed base for a single item, they probably can be ignored, unless the installation of new AGE or a new shop requires power or air-conditioning or buildings beyond those already installed. If heavy duty equipment is required, it is possible that lengthy amortization policies and multiple use aspects can minimize the impact of facility additions in a single-item evaluation. These costs must be considered, however, as items are aggregated and/or AGE units are assembled into shop sets and organized by Table of Allowance. In addition, where bare base operations must be considered, the mobility penalty of deploying a large facilities package must be directly related to the repair benefit it produces. The model can be used to make this evaluation.

To summarize--most facilities units have joint use potential, and the decisionmaker must decide the allocation of cost, weight, and amortization schedule for a particular evaluation. Once this is done, the model will develop the applicable cost benefit apportionment. In general, the higher the facilities cost allocated to the item-AGE set, the less likely that local repair would be justified. If costs are high and specific to a given shop or item such as an LSAT or air-conditioner, even the highest-cost, highest-demand items cannot justify dispersed repair facilities on the basis of the cost-benefit evaluation.

AGE GROUPS

While item by item cost-benefit analyses are useful, they may not be straightforward because of the joint-use characteristics of most AGE items. For example, the costs of a single unit of AGE may be allocated among all the items it repairs, or alternatively the composite-weighted demand characteristics of all items may be evaluated against a unit of AGE. These evaluations may produce different results, neither of which is appropriate when the total AGE-repair environment is considered. The solution used in RM-3845-PR to aggregate AGE and items by shop may be more appropriate when allocation and amortization problems are difficult to resolve.

Since the AGE itself must be sited in suitable environments and must be maintained and calibrated by other AGE, some of these costs should be allocated to the cost of doing base level repair. Facilities costs are discussed above. The cost of AGE can probably be developed as it was for the PACER SORT exercise, through the development of AGE family trees.* This method grouped the AGE and all supporting equipment by Airborne Work Unit Code and thus related the AGE to the recoverable end items. This method does not fully resolve the problem of allocating costs completely, as some AGE can be used on more than one WUC set, but it is convenient for data collection and analysis purposes.

In evaluating the cost of repair, no mention has been made of the quantity of AGE required at either the base or depot level to do the repair task that the item parameters imply. Only the cost of one unit of AGE or AGE shop set is used in the model. (The model can, however, accept the cost of multiple units of AGE if the user has specific knowledge of the number of units that are necessary for base location differences or desired deployment postures.) The reason for this is that, in general, AGE units are under-utilized and queues rarely form in the repair process for most recoverable items. In

---

*Project PACER SORT - Final Report. Vol. I, Part IV, I-IV-D, Hq AFLC, 30 Jun 1967.

estimating depot costs, the cost of a single unit is also used since even though the depot receives recoverables from many bases, usually it is possible to operate with only a single AGE unit. For most recoverable items, economies of scale are not great. The depot also has the option of work scheduling and multi-shift operation to smooth the workload and minimize the impact of queueing, except on the very high demand items. In any event, the model user can use a single unit of AGE or a set of AGE, and can evaluate a range of alternatives

As a final note, once a decision to position the AGE or a shop set of AGE has been made on the basis of the foregoing analysis, one should expect that some AGE may show very low utilization rates. However, AGE utilization itself is not a true measure of its value to the support process.

ITEM GROUPINGS

Item groupings are another method of avoiding arbitrary joint cost decisions. However, the method of developing item or system groupings for analysis purposes may present some difficulties. As an example of the type of allocation problems that may be encountered in the evaluation of the value of multi-use AGE, the following situation can be posed. Assume that a particular unit of AGE (a test bench) can be used to repair three different items. The items and the AGE unit have the characteristics shown in Table 2.

Table 2

ITEM CHARACTERISTICS

Item	$ Value	Daily Demand Rate	Weight (lbs)
A	10,000	.07	200
B	1,000	.03	20
C	5,000	.10	50
AGE	50,000	--	2000

All other parameters that describe the end items and the support situation were identical and were held constant throughout the example.

Using PRAM, we made the runs shown in Appendix C. The item evaluations were made by allocating the cost and weight of the AGE in proportion to the daily demand rates (DDRs) of each of the using items. Referring now to the individual analysis for each of the items (A, B, and C) as shown in Appendix C, we have aggregated the five-year total costs for each item (Table 3).

Table 3

FIVE YEAR TOTAL COSTS

Item	No AGE ($)	AGE Available ($)
A	77,783	47,488
B	8,350	9,142
C	56,297	43,982
Total	142,430	100,612

It is quite clear from this example that the AGE available case costs are much lower than the alternative, and the decision to buy the AGE to support all three items appears justified. Analysis of the individual item decisions would not be appropriate since the allocation of AGE weight and costs is artificial, as Table 4 indicates.

Table 4

AGE ALLOCATION METHOD

Item	$ Value	DDR	Unit Wt	Allocated AGE Cost	Allocated AGE Wt	No AGE Lowest Cost?
A	10,000	.07	200	17,500	700	No
B	1,000	.03	20	7,500	300	Yes
C	5,000	.10	50	25,000	1000	No
Composite	6,150	.20	92	50,000	2000	No

The above table also shows the characteristics of a composite item representing an alternative method of making the same evaluation. The parameters defining this item represent the weighted average of each of the characteristics of items A, B, and C. They are weighted in proportion to the DDR, and the composite item DDR is the sum of

the individual DDR items. Evaluation of this item is clearly in the direction of the AGE Available cost also. Appendix C reveals the No AGE case costs to be $115,576, and the AGE Available costs $85,375.

We do not recommend the use of the composite item approach, since the aggregation of DDRs tends to bias the cost evaluation toward the No AGE case, even though this was not the case in the example. The bias is caused by the stockage model pooling effect, which reduces the total stockage costs of the composite item.

Any analysis involving allocated, composite or joint costs requires rigorous and detailed evaluation by the decisionmakers. All alternatives need to be investigated, especially during the provisioning process, before maintenance and mobility concepts are defined. During provisioning, most support alternatives are still open, and the method of evaluation used may have a large impact on future system support concepts and costs. In all probability, the decision process would have greater provisioning implications if it were made on an item basis considering the repair AGE set as a unit rather than the other way around. The decision would affect both the item requirements for stock levels and the AGE provisioning process simultaneously. Such decisions are joint in nature, and the model could provide an evaluation of the cost structure over a range of near-optimal stockage-repair policy alternatives.

IV. CONCLUSIONS

In Sec. I, we emphasized the importance of the RLD process in terms of its impact on the resource allocation process. Once the selection of a weapon system for a particular role or mission had been made, the development of a maintenance and support concept had to be refined to the equipment level. In this instance, the RLD process was either dictated by the operational requirements of the weapon or evaluated in some model or decision process that estimated the cost-benefit relationships. The model described here would be useful in making this type of initial evaluation.

In a typical weapon life cycle, this kind of evaluation would most likely take place after the development contract had been completed and the initial production designs were underway. It would be part of the AGE provisioning process, since much of the data required for model operation would have to come after the AGE had been designed or conceptually defined. Most data would be available prior to the publishing of the Consolidated Aerospace Ground Equipment List (CAGEL) required for AGE provisioning. This list provides information on the size, weight, power and environmental requirements, and cost of the AGE. It also defines the calibration and test equipment required and lists the end items AGE services. With this information available, the model can be properly employed in the initial provisioning process.

There are possible other applications, at least two of which may have use after the weapon is in the field and the initial conceptual and provisioning decisions are made. The first is the use of the model in evaluating alternative mobility postures. In this evaluation, the model can be used to estimate the repair demands of the deployed unit and the cost-benefit relationship of various AGE spares postures. The mobility parameters of a range of possible postures can be developed and the break-even cost-benefit points for various item-AGE combinations can be portrayed for the decisionmakers.

The second application has relevance to the modification review process. Whenever an extensive design change or modification is being contemplaced in order to improve the performance, reliability, or

maintainability of a recoverable end item, some estimate of the modification's impact on the repair process must be made. Given an estimate of the changes in failure patterns, NRTS rates and repair AGE requirements, the model can be employed to reestimate the cost-benefits surface. These reestimates could result in changes to the repair concept, mobility concept, or both.

It is obvious that system managers must continually make decisions that have logistics impacts on both the operational and support commands. These decisions must be continually revised and evaluated. A model such as the one described herein may be useful in systematically organizing the decision variables into cost-benefit displays for easy communication to all elements in the decision process.

Appendix A

JOSS PROGRAM

```
Delete all.
Use file 5[illegible] (A0680).
Roger.
Recall item 1 (age).
Done.
Type all parts.

1.01 Set D=24.
1.02 Type "Cost of base repair in $/mmh?".
1.03 Demand d(1).
1.04 Type "Cost of depot repair in $/mmh?".
1.05 Demand d(2).
1.06 Type "Shipping cost ($/lb)?".
1.07 Demand d(3).
1.1 Type "Daily demand rate of the end item?".
1.2 Demand L.
1.3 Type "Order and shipping time (days)?".
1.4 Demand T.
1.5 Type "Max no. of units in backorder condition?".
1.7 Demand B.
1.72 Type "Cost of unit end item ($)?".
1.73 Demand p.
1.9 Type "Cost of AGE ($)?".
1.91 Demand P.
1.911 Type "Life of AGE (yrs)?".
1.912 Demand y.
1.915 Type "Weight of AGE (lbs)?".
1.916 Demand g.
1.92 Type "No checked-repaired actions?".
1.921 Demand n(1).
1.922 Type "No checked-found-servicable actions?".
1.923 Demand n(2).
1.924 Type "No NRTS actions?".
1.925 Demand n(3).
1.926 Type "No Condemned?".
1.927 Demand n(4).
1.93 Type "Mean time checked-and-repaired (hrs)?".
1.933 Demand a(1).
1.9331 Set a(1)=a(1)/D.
1.934 Type "Mean time checked-found-servicable (hrs)?".
1.936 Demand a(2).
1.9361 Set a(2)=a(2)/D.
1.94 Set N=n(1)+n(2)+n(3)+n(4).
1.941 Do part 2.

2.01 Type "Unit weight?".
2.011 Demand W.
2.02 Type "Repair manhours per job to fix?".
2.021 Demand r.
2.03 Type "Repair manhours per job to find servicable or condemn?".
2.031 Demand l.
2.1 Type "Cost of additional tech data ($)?".
2.11 Demand u(1).
2.12 Type "Weight of additional tech data (lbs)?".
```

Preceding Page Blank

```
2.13 Demand u(2).
2.14 Set U = u(1) + [(u(2))•(d(3))].
2.2 Type "Allocated annual cost of facillities and power ($)?".
2.21 Demand m(1).
2.22 Type "Weight of facilities and power (lbs)?".
2.23 Demand m(2).
2.24 Set M = m(1) + [(m(2))•(d(3))].
2.3 Type "Cost of additional spares for AGE and end-items ($)?".
2.31 Demand z(1).
2.32 Type "Weight of additional spares (lbs)?".
2.33 Demand z(2).
2.34 Set Z = z(1) + [(z(2))•(d(3))].
2.41 Type "Discount factor?".
2.42 Demand h.
2.43 Set h=1-h.
2.44 Set H=(1-h*5)/(1-h).
2.5  Do part 9.

3.1 Set w = [(d(2))•r + (d(3))•2•W]•L•360.
3.2 Set b(1)=[n(1)/N]•d(1)•L•r•360.
3.205 Set b(5)=[(n(2)+n(4))/N]•L•1•d(1)•360.
3.21 Set b(2) = [(n(3))/N]•W•360•L•2•(d(3)).
3.22 Set b(3) = L•[(n(3))/N]•(d(2))•360•r + P/y.
3.23 Set b(4)=b(1)+b(2)+b(3)+b(5)+U+Z+M/y.
3.3 Set K(1) = [Q(2)]•W•(d(3)) + H•b(4).
3.4 Set K(2) = g•(d(3)) + K(1).
3.5 Set K(3) = Q(1)•W•d(3) + H•w.
3.6 Set K(4) = K(3) + C(1).
3.7 Set K(5) = K(2) + C(2).

7.11 Do part 10.
7.12 Do part 20.
7.13 Line.
7.14 Line.
7.2 Type form 1.
7.21 Line.
7.3 Type Q(1),Q(2) in form 2.
7.31 Line.
7.4 Type C(1),C(2) in form 3.
7.41 Line.
7.5 Type w,b(4) in form 4.
7.51 Line.
7.6 Type K(3),K(2) in form 5.
7.61 Line.
7.7 Type K(4),K(5) in form 6.
7.71 Line.
7.8 Type B,B in form 7.

8.05 Do step 20.1.
8.11 Set q(1)=L•[(n(1)+n(2))/N]•a(1).
8.12 Set q(2)=L•[(n(3)+n(4))/N]•t.
8.13 Set q(3)=sqrt[3•(q(1)+q(2))].
8.14 Set Q(2)=ip[q(1)+q(2)+q(3)].
8.141 Set Q(2)=Q(2)+1 if fp[q(1)+q(2)+q(3)]≥.5.
```

```
8.15 Set A(2)= S(Q(2)).
8.21 Set q(4)=L·T.
8.22 Set q(5)=sqrt[3·q(4)].
8.23 Set Q(1)=ip[q(4)+q(5)].
8.231 Set Q(1)=Q(1)+1 if fp[q(4)+q(5)]≥.5.
8.24 Set t=T.
8.25 Set A(1)=S(Q(1)).
8.26 Set C(1)=Q(1)·p.
8.27 Set C(2)=Q(2)·p.
8.3 Do part 3.
8.41 Line.
8.42 Line.
8.43 Type form 1.
8.431 Line.
8.44 Type Q(1),Q(2) in form 8.
8.441 Line.
8.45 Type C(1),C(2) in form 3.
8.451 Line.
8.46 Type w,b(4) in form 4.
8.461 Line.
8.47 Type K(3),K(2) in form 5.
8.471 Line.
8.48 Type K(4),K(5) in form 6.
8.481 Line.
8.49 Type A(1),A(2) in form 7.

9.1 Do part 7.
9.2 Do part 8.
9.3 Page.

10.1 Set t=T.
10.2 Set s=1.
10.4 To step 10.5 if S(s)≤B.
10.41 Set s=s+1.
10.42 To step 10.4.
10.5 Set C(1)=s·p.
10.6 Set Q(1)=s.

20.1 Set t=T·[(n(3)+n(4))/N]+a(1)·(n(1)/N)+a(2)·(n(2)/N).
20.2 Set s=1.
20.4 To step 20.5 if S(s)≤B .
20.41 Set s=s+1.
20.42 To step 20.4.
20.5 Set C(2)=s·p.
20.6 Set Q(2)=s.
20.7 Do part 3.


Type all forms.

Form 1:
                                    No AGE        AGE Available
```

Form 2: Optimal Stock Level	____	____
Form 3: Total Stockage Cost	$______	$______
Form 4: Yearly operating cost	$______	$______
Form 5: 5-Year Operating Costs	$______	$______
Form 6: 5-Year Total Cost	$______	$______
Form 7: Avg No Units in Backorder	__.__	__.__
Form 8: Chapt 11 Stock Level	____	____

Appendix B

JOSS EXAMPLE

	No AGE	AGE Available
Optimal Stock Level	19	8
Total Stockage Cost	\$ 19000	\$ 8000
Yearly operating cost	\$ 25920	\$ 26732
5-Year Operating Costs	\$ 106620	\$ 110921
5-Year Total Cost	\$ 125620	\$ 118921
Avg No Units in Backorder	.050	.050

	No AGE	AGE Available
Chapt 11 Stock Level	18	6
Total Stockage Cost	\$ 18000	\$ 6000
Yearly operating cost	\$ 25920	\$ 26732
5-Year Operating Costs	\$ 106595	\$ 110871
5-Year Total Cost	\$ 124595	\$ 116871
Avg No Units in Backorder	.082	.184

Appendix C

ITEM ALLOCATION EXAMPLE

p=10000
L=.07
W=200
P=17500
g=700
Do part 4.

Item A

	No AGE	AGE Available
Optimal Stock Level	6	3
Total Stockage Cost	$ 60000	$ 30000
Yearly operating cost	$ 4284	$ 4207
5-Year Operating Costs	$ 17783	$ 17488
5-Year Total Cost	$ 77783	$ 47488
Avg No Units in Backorder	.010	.010

	No AGE	AGE Available
Chapt 11 Stock Level	5	2
Total Stockage Cost	$ 50000	$ 20000
Yearly operating cost	$ 4284	$ 4207
5-Year Operating Costs	$ 17743	$ 17448
5-Year Total Cost	$ 67743	$ 37448
Avg No Units in Backorder	.028	.032

p=1000
L=.03
W=[illegible]
P=[illegible]0
g=300
Do part 9.

Item B

		No AGE		AGE Available
Optimal Stock Level		4		2
Total Stockage Cost	$	4000	$	2000
Yearly operating cost	$	1058	$	1727
5-Year Operating Costs	$	4350	$	7142
5-Year Total Cost	$	8350	$	9142
Avg No Units in Backorder		.010		.010

		No AGE		AGE Available
Chapt 11 Stock Level		3		1
Total Stockage Cost	$	3000	$	1000
Yearly operating cost	$	1058	$	1727
5-Year Operating Costs	$	4346	$	7138
5-Year Total Cost	$	7346	$	8138
Avg No Units in Backorder		.016		.034

p=5000
L=.10
W=50
P=25000
g=1000
Do part 9.

Item C

	No AGE	AGE Available
Optimal Stock Level	8	4
Total Stockage Cost	$ 40000	$ 20000
Yearly operating cost	$ 3960	$ 5798
5-Year Operating Costs	$ 16297	$ 23982
5-Year Total Cost	$ 56297	$ 43982
Avg No Units in Backorder	.010	.010

	No AGE	AGE Available
Chapt 11 Stock Level	6	2
Total Stockage Cost	$ 30000	$ 10000
Yearly operating cost	$ 3960	$ 5798
5-Year Operating Costs	$ 16277	$ 23962
5-Year Total Cost	$ 46277	$ 33962
Avg No Units in Backorder	.051	.082

Composite Item

	No AGE	AGE Available
Optimal Stock Level	13	6
Total Stockage Cost	$ 79950	$ 36900
Yearly operating cost	$ 9130	$ 11713
5-Year Operating Costs	$ 37626	$ 48475
5-Year Total Cost	$ 117576	$ 85375
Avg No Units in Backorder	.010	.010

	No AGE	AGE Available
Chapt 11 Stock Level	10	4
Total Stockage Cost	$ 61500	$ 24600
Yearly operating cost	$ 9130	$ 11713
5-Year Operating Costs	$ 37571	$ 48438
5-Year Total Cost	$ 99071	$ 73038
Avg No Units in Backorder	.077	.053

DOCUMENT CONTROL DATA

1. ORIGINATING ACTIVITY	2a. REPORT SECURITY CLASSIFICATION
THE RAND CORPORATION	UNCLASSIFIED
	2b. GROUP

3. REPORT TITLE

PRAM: A PRELIMINARY REPAIR LEVEL ANALYSIS MODEL

4. AUTHOR(S) (Last name, first name, initial)

Kaplan, Richard J., John Y. Lu and Robert M. Paulson

5. REPORT DATE	6a. TOTAL No. OF PAGES	6b. No. OF REFS.
September 1968	48	---

7. CONTRACT OR GRANT No.	8. ORIGINATOR'S REPORT No.
F44620-67-C-0045	RM-5752-PR

9a. AVAILABILITY / LIMITATION NOTICES	9b. SPONSORING AGENCY
DDC-1	United States Air Force Project RAND

10. ABSTRACT

A description of a JOSS model, developed for the PACER TACK study, to analyze the cost tradeoffs between alternative repair level decisions. In deciding whether recoverable items should be repaired at the operating base or at a central depot, and whether AGE should be deployed to forward areas, the costs of AGE, AGE spares, facilities, personnel, and technical data must be balanced against the advantages of on-base repair, such as shorter turnaround time, flexibility, local control, self-sufficiency, reduced inventory cost, reduced shipping costs. PRAM, the Preliminary Repair Level Decision Analysis Model, uses the method of marginal analysis to determine the minimum-cost stock level to achieve a specified performance criterion. Given 26 simple inputs, PRAM outputs for each case (AGE available or not available at base) the (1) optimal stock levels by the METRIC standard and, if desired, by the AFM 67-1 method; (2) total stock cost; (3) yearly operating cost; (4) five-year operating cost; (6) five-year totals. Recomputation with one changed input requires less than one minute.

11. KEY WORDS

JOSS
PRAM (Preliminary repair Level Analysis Model)
Inventory control
AGE (Aerospace Ground Equipment)
Maintenance
Cost analysis
PACER TACK (Project)
Bases
Depots